E-ISSN: 2349-7610

INTERNATIONAL JOURNAL FOR RESEARCH IN EMERGING SCIENCE AND TECHNOLOGY, VOLUME-1, ISSUE-3, AUGUST-2014

Analysis of Microstrip Finger on bandwidth of Interdigital band Pass Filter using Artificial Neural Network

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ABSTRACT

In this paper, a novel method of bandwidth estimation using variation of finger length on interdigital band pass filter has been presented using artificial neural networks for desired frequency range between 1.5--3.5GHz. Interdigital filter is multifinger periodic structure which offers compact filter design space. An ANN model has been developed and tested for estimating the cut off frequency of band pass filter and performance is evaluated in terms of mean square error and concluded that RBF network is more accurate than MLPFFBP. The proposed method of design provides the exact bandwidth for particular finger length of filter without using painstaking calculation.

Keyword - Artificial neural networks (ANN), Multi layer Perceptron feed Forward back propagation (MLPFFBP), Interdigital capacitor (IDC), Mean square error (MSE), Radial Basis Function (RBF), Artificial neural network (ANN), Levenberg Marquardt (LM).

1. INTRODUCTION

In modern communication systems, high performance and small size band pass filters are essentially required to enhance the system performance and to reduce cost of fabrication. Existing Parallel coupled microstrip filters have been widely used in the RF front end of microwave and wireless communication systems for decades. But their large size was problematic with the RF system where size is important consideration [1-2]. To overcome existing drawback, Interdigital capacitor (IDC) geometry is used in which gaps meanders back and forth in a rectangular area forming two sets of fingers that are interdigital. IDC is a multifinger periodic structure which offer very high Q value in compact design space with microstrip finger coupled between the input and output ports across the gaps, hence increase performance of filter. [3]

In present work, an attempt has been made to utilize the potential of neural network to calculate the cut off frequency of filter using data from design parameter. ANN model has been established by learning from microwave data which was acquired by EM simulation of filter design in CST (computer simulation technology) Microwave environment and results are used as standard to train the network through a process called training. An ANN model based on Radial basis function and feed forward back propagation algorithms are used to train the network and determine Fu (upper cut off) and Fl (lower cut off) and hence bandwidth (Fu - Fl) of filter for desired frequency range of 1.5-3.5 GHz.

2. PROPOSED FILTER DESIGN AND DATA GENERATION

Interdigital capacitor (IDC) is an element for producing high pass characteristic using microstrip finger lines used for filter design. Number of Fingers (N) provide coupling between the input and output ports across the gaps. Typically, the gaps between finger and end of the fingers are equal to reduce parasitic capacitance. [3]

The length (L) and width (W) of the finger determined total capacitance and capacitance per unit length along the width of

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INTERNATIONAL JOURNAL FOR RESEARCH IN EMERGING SCIENCE AND TECHNOLOGY, VOLUME-1, ISSUE-3, AUGUST-2014

the finger. The total capacitance of an interdigital structure(*C*) expressed as:

$$C = (\varepsilon r + 1).l\,[(N-3)A1 + A2] \qquad (1)$$

For a finite substrate (Ɛr), the effect of *h* (height of substrate) must be included in A1 and A2. In the final design, usually *S (*gap between finger*)* =*W* and, *l* ≤ ʎ /4. Approximate expressions for *A*1 and *A*2 (design constant) are as [2, 5]:

$$A1 = 4.409 \tanh\left[0.55\left(\frac{h}{W}\right)^{0.45}\right] \times 10^{-6} \qquad (2)$$

$$A2 = 9.92 \tanh\left[0.52\left(\frac{h}{W}\right)^{0.5}\right] \times 10^{-6} \qquad (3)$$

$$C_S = \frac{1}{2}\frac{\sqrt{\varepsilon_r}}{Z_0 c}\, l \qquad (4)$$

$$L = \frac{Z_0\sqrt{\varepsilon_{re}}}{c}\, l \qquad (5)$$

The filter with Number of Fingers (N) =10, was designed to work for frequency range of 1.5-3.5 GHz with L=34mm and W=S=2mm respectively. The length and width of the filter design are calculated by the given equation (1), (2), (3), (4) & (5).

As total capacitance value depends on length of finger strip ,Fig 1 shows the proposed geometry with finger length varied between L = 34mm to L"= 24mm to extract response such that it can be used to train the neural network and estimate the bandwidth of filter. MATLAB neural tool box has been used to calculate the cut off frequency of band pass filter i.e. F_u (upper cut off frequency) and F_l (lower cut off frequency) for different training algorithm and results are compared with EM simulation on basis of mean square error of ANN.

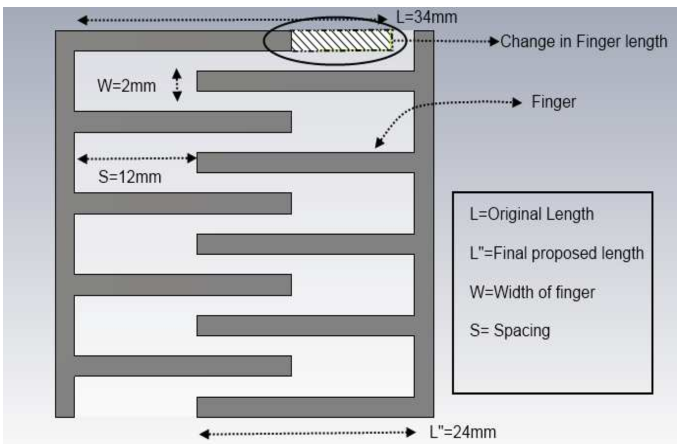

Fig.1: Proposed Interdigital filter structure

3. NEURAL MODEL FOR FILTER

The ANN model developed for Microstrip band pass filter is shown in Fig 2. The feed forward back propagation and radial basis network has been utilized to calculate the lower (F_l) and upper cut off frequency (F_u) of the band pass filter by providing Length (L), Width (W) and substrate (Ɛr) as input to network. To analyze neural model for filter design 180 different inputs for desired frequency range of operation has been utilized for training of neural model using Levenberg Marquardt (LM) and radial basis function and 20 test patterns are used to validate the accuracy of neural model for best performance.

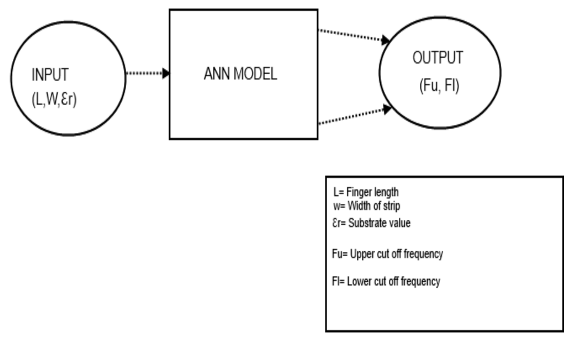

Fig-2: ANN model for Band pass filter

3.1. Multi Layer Feed Forward Back Propagation (MLFFBP) Neural Network

MLP network are supervised networks, they required a desired response to be trained. With one or two hidden layers they can approximate virtually any input output map. The weights of the network are usually computed by training the network using the back propagation algorithm. [8] In present, work three layers multilayer Perceptron feed-forward back propagation neural network with one hidden layer are trained by LM algorithm. The network is analysed with different number of hidden layers and also the numbers of processing elements are also varied to acquire the accuracy. It is concluded that three layer
MLPFFBP with one hidden layer and 20 processing elements in hidden layers is the optimum structure for proposed problem. There are three input neurons in the input layer, 20 hidden neurons in the hidden layer and two output neurons in

E-ISSN: 2349-7610
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the output layer. The training of network performs in 71 epochs so as to reduce the average MSE close to 4.41e-05.

The network has been trained for different IDC finger length but in a specified range (34mm-24mm). During the training process the neural network automatically adjusts its weights and threshold values such that the error between predicted and sampled outputs is minimized [9]. The adjustments are computed by the back propagation algorithm. The transfer function preferred is tansig for neural network. In table 1 lower cut off frequency obtained using CST software and using LM algorithm for different test patterns are compared and mean square error has been calculated.

Finger length (mm)	Freq lower (GHz) CST	Freq lower (Ghz) LM	MSE (LM)
33.8	1.820	1.8087	0.000135
33.45	1.825	1.8219	1.44E-05
33.2	1.832	1.8277	2.02E-05
32.85	1.842	1.8351	5.93E-05
32.3	1.862	1.8642	4.41E-06
32	1.880	1.8939	0.00018
31.55	1.923	1.9331	9.8E-05
31.15	1.948	1.9506	3.61E-06
30.8	1.961	1.9589	4.84E-06
30.4	1.973	1.9671	4.62E-05
30.15	1.981	1.9732	6.24E-05
29.75	1.990	1.9862	1.68E-05
28.35	2.074	2.0809	4.36E-05
27.85	2.113	2.1248	0.000121
27.1	2.182	2.1797	5.76E-06
26.3	2.238	2.2354	9.61E-06
25.9	2.268	2.2703	2.25E-06
25.35	2.304	2.2994	2.4E-05
24.95	2.353	2.3589	2.7E-05
24.35	2.422	2.42	5.29E-06

Table 1: Comparisons of results obtained using CST and LM algorithm on basis of mean square error for analysis of Band pass filter.

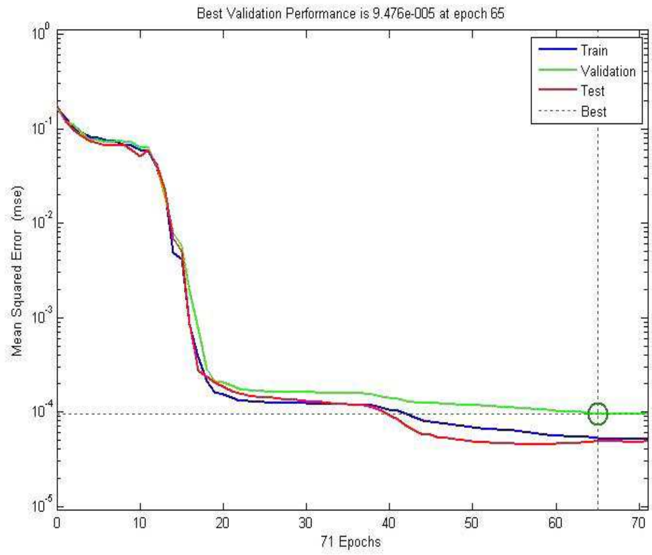

Fig-3: Number of epochs to achieve minimum mean square error level in case of MLFFBP with LM training algorithm

3.2. RBF Network

Radial basis function network is a feed forward neural network with a single hidden layer that use radial basis activation functions for hidden neurons. The RBF neural network has both a supervised and unsupervised component to its learning.

It consists of three layers of neurons—input, hidden and output. The hidden layer neurons represent a series of center in the input data space. Each of these centres has an activation function, typically Gaussian [8-9].

In present work the spread value for RBF network was chosen as 1.1, which gives the best accuracy. The network was trained with 180 samples and tested with 20 samples. RBF network with accuracy of 99.3% is more accurate compared to MLPFFBP for filter design. The RBF network automatically adjusts the number of processing elements in the hidden layer till the defined accuracy is reached. Fig.4 shows the training performance of the neural network model is trained in 175 epochs with MSE = 1.13173e-005. Table 2 shows results obtained using CST software and RBF network for different test patterns are compared.

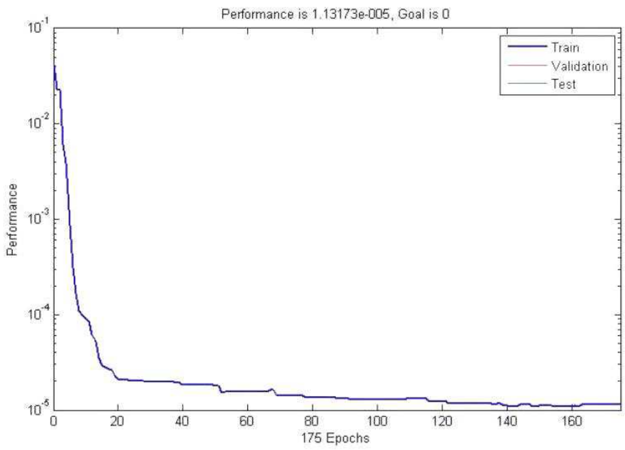

Fig-4 Number of epochs to achieve minimum mean square error level in RBF Network

Finger length (mm)	Freq lower (GHz) CST	Freq lower (GHz) RBF	MSE (RBF)
33.8	1.820	1.812	0.00016
33.45	1.825	1.8221	3.14E-05
33.2	1.832	1.8327	1.21E-06
32.85	1.842	1.8425	8.41E-06
32.3	1.862	1.8614	0.000016
32	1.880	1.8833	1.52E-05
31.55	1.923	1.9226	8.1E-07
31.15	1.948	1.946	9E-08
30.8	1.961	1.9623	4.9E-07
30.4	1.973	1.9739	8.1E-07
30.15	1.981	1.9797	6.4E-07
29.75	1.990	1.9921	9E-08
28.35	2.074	2.0726	6.25E-06
27.85	2.113	2.1176	8.41E-06
27.1	2.182	2.1823	5.76E-06
26.3	2.238	2.2382	2.21E-05
25.9	2.268	2.27	1.68E-05
25.35	2.304	2.2996	3.84E-05
24.95	2.353	2.3594	1.3E-05
24.35	2.422	2.4205	2.92E-05

Table 2: Comparisons of results obtained using CST and RBF on basis of mean square error for analysis of Band pass filter

4. RESULT

The paper provides the effects of variation of finger length on bandwidth of interdigital band pass filter. It has been observed that the both F_u & F_l cut off frequency start shifting toward high frequency end by reducing the finger length during simulation, which provides better understanding that for given filter design by reducing length of finger strip, we can shift operating frequency towards higher frequency. The mean absolute percentage error (MAPE) for LM training is 1.512 % whereas for RBF network is 0.6532%, which shows that experimental results generated by radial basis method are more fast and accurate.

Figure-5 shows comparison of LM and RBF algorithm based on mean square error of output cut off frequency and observed that RBF algorithm provide low value of performance goal indicating that trained ANN model is an accurate model for filter design.

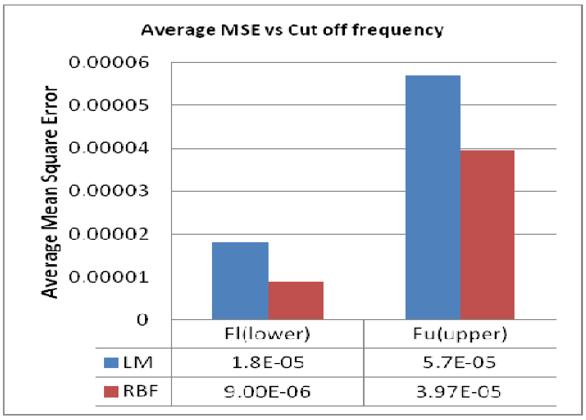

Fig-5: Graph showing comparison of Average mean square error for Levenberg-Marquardt and RBF ANN Algorithm

5. CONCLUSION

An efficient and time saving method for calculation of bandwidth of filter was discussed using ANN. The results obtained with the present technique are closer to the experimental results generated by simulating interdigital filter using CST software on the FR4 (Lossy) substrate. The paper concludes that results obtained using present ANN techniques are quite satisfactory and followed the experimental drift and also that RBF is giving the best approximation to the design as compared to MLFFBP. In the analysis, one can select the exact value of finger length to obtain desire set of cut off frequency over working frequency range without using laborious calculation.

6. ACKNOWLEDGMENT

Authors acknowledge the support and valuable guidance received from Dr. V. V. Thakare, Department of Electronics, Madhav Institute of Technology and Science Gwalior, India in preparation of this paper.

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